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Saving–investment Correlations in Response to Monetary Policy Shocks: New Insights into the Feldstein–Horioka Puzzle?

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Abstract In this paper, it is argued that the observed high positive correlation between national savings and investment which is found in the data can in part be explained by shocks to monetary policy. This hypothesis, which is established by reviewing some empirical findings, is tested in a two-country DSGE-model framework in the tradition of the New Open Economy Macroeconomics. The simulation results obtained support the idea that shocks to monetary policy might contribute to the explanation of the Feldstein-Horioka puzzle.

Keywords Saving–investment correlations · Monetary policy shocks · Feldstein–Horioka puzzle · Local-currency pricing

JEL Classification E2 · E52 · F32

1 Introduction

In their seminal contribution, Feldstein and Horioka (1980) investigated the degree of capital mobility by running cross-sectional regressions of gross domestic investment rates on gross domestic saving rates. For the 16 OECD countries considered, the estimated saving-retention coefficient—interpreted as the share of an exogenous increase in savings that will remain in the domestic country—was 0.887 for 15-year averages from 1960 to 1974. With high capital mobility this finding is difficult to explain in classical models, since for given investment opportunities, an increase in one country's saving should

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lead to a proportionate increase in investment in all countries. However, the results found by Feldstein and Horioka suggested that about 90% of an increase in one country's savings are invested in the domestic economy. This result has inspired a large number of subsequent studies either employing more recent data and/or different estimation procedures. Rather surprisingly, the high correlation between domestic investment and domestic saving has been reproduced in most studies, although the coefficient seems to have declined in recent years.[1]

The high correlations between domestic savings and investment ratios found in the data, however, do not need to imply a low degree of capital mobility. Instead, as shown by e.g. Baxter and Crucini (1993), but also Cardia (1991), Finn (1990) and Mendoza (1991), time-series correlations of savings and investment in the range of the data are obtained in dynamic stochastic general equilibrium (DSGE) models featuring perfect capital mobility if shocks to productivity are the major source of variability. Baxter and Crucini derive a two-country real business cycle model and show that the correlation induced by shocks to productivity is higher, the larger the size of the country. Finn as well as Mendoza consider the effects of shocks to productivity in a small open economy, where Mendoza compares the resulting variations to historical data of Canada. Cardia investigates a combination of productivity, fiscal and monetary shocks in a small open economy DSGE-model, where she finds that shocks to productivity cause high time-series correlations of savings and investment in the model, while shocks to fiscal and monetary policy seem to add little to the correlation.

Yet, empirical evidence by Kim (2001) suggests that shocks to productivity alone are not sufficient to explain the correlations found in the data. Kim uses annual panel data from 1960 to 1992 for 19 OECD countries and controls for cyclical shocks in order to test the significance of business cycle shocks in explaining the saving-investment correlations. Surprisingly, controlling only for productivity shocks merely reduces the saving-retention coefficient from 0.69 to 0.64.[2] These results suggest that shocks other than to productivity also play an important role for the correlations of savings and investment found in the data.

[1]For cross-sectional data from 1960 to 1984 Tesar (1991) estimated saving-retention coefficients varying between 0.79 and 0.95. Obstfeld and Rogoff (1995b) found a coefficient of 0.622 for a sample of 22 OECD countries over the decade 1982–1991. Using data from 1974 to 1990, Obstfeld (1995) estimated both time-series and cross-sectional correlation coefficients for savings and investment ratios for OECD countries. In the cross-sectional estimation spanning the whole period, the coefficient is 0.715. If different sub-samples are considered, the coefficient is decreasing over time. In the time-series analysis the coefficients vary. Yet, for most countries, domestic savings and investment are positively linked and the relationship is rather strong. In general, the correlation is found to be rather lower for smaller countries. For the US, the estimated time-series correlation was 0.773. For a broad survey on these and related studies see Coakley et al. (1998).

[2]When controlling for all three different types of cyclical shocks considered (i.e. productivity, fiscal and terms of trade shocks), the estimated saving-retention coefficient is reduced from 0.69 to 0.42, but still remains at a significant level above zero.

One alternative source of shocks are shocks to monetary policy. Although monetary policy is not likely to affect savings and investment decisions in the long run, it might well account for short-run variations in these variables. Kim (2001) studies the effects of US monetary policy shocks by estimating vector autoregressions, where he also analyzes the effects on domestic investment and savings. The impulse response functions obtained for quarterly data from 1974 to 1996 illustrate that in response to both expansionary monetary policy shocks considered, US savings and investment rise significantly for a number of periods. Since the impulse responses of the two variables are both similarly hump shaped, Kim's results indicate—at least for the US—that in the short run monetary policy will affect savings and investment in a similar way, and might therefore explain in part the correlations found in the time-series data.

In this paper, I analyze whether a positive correlation of domestic savings and investment in response to a monetary policy shock can also be obtained in a theoretical two-country DSGE-model with capital mobility in the tradition of the New Open Economy Macroeconomics (NOEM).[3,4] It will be shown that this type of model is able to reproduce a high correlation of domestic savings and investment, both for a single permanent shift in money supply as well as for an exogenous process of money supply. In response to a single permanent increase in the home money supply, both savings and investment in the home economy rise in the short run. The similarity of the savings and investment responses is higher, the bigger the relative size of the home economy. This effect is de facto independent of the price setting behavior of firms, which can either be producer-currency pricing (PCP) or local-currency pricing (LCP). This does not apply to the foreign country. For the assumption of PCP, both investment and savings in the foreign country rise in response to the home monetary expansion and thus exhibit a high degree of correlation. Yet, with LCP, foreign investment initially falls, while savings in the foreign country still increase. As a result, there is no correlation of foreign savings and investment in response to a home monetary policy shock. For the simulation of a sequence of shocks to both home and foreign money supply, the resulting correlation of savings and investment is high in both countries, independent of the price-setting behavior of firms. Yet, the correlation is lower for smaller countries. Overall, the simulation results suggest that shocks to monetary policy might in part account for the time series correlation of domestic savings and investment.

The structure of the paper is as follows. In the next section, the model is derived, the parameter values of the model are calibrated and the properties of the assumed money supply process are discussed. Section 3 presents the results. In a first part, the impulse response functions for the relevant home and foreign variables in response to a single permanent 1% increase in home

[3] For a survey of this branch of research initiated by Obstfeld and Rogoff (1995) see Lane (2001) and Sarno (2001).

[4] Although Cardia (1991) includes monetary shocks in her analysis of the Feldstein–Horioka puzzle in a small open economy model, she does not consider the effects of monetary shocks on savings and investment separately. Besides, she does not include price rigidities, and she only considers a small open economy.

money supply are presented and discussed for illustrational purpose. The effects of alternative price-setting strategies as well as of the country size are discussed. In a second part, the money supply process is simulated and the resulting simulation outcomes are analyzed and compared to the stylized facts obtained for the US. Section 4 concludes.

2 The model

In the following, a two-country dynamic general equilibrium model with nominal price rigidities is derived.[5] The world consists of two countries, home and foreign. In order to account for the impact of the country size on the resulting saving-investment correlations, the relative country size is allowed to vary. Both world population and the continuum of individual monopolistic firms are normalized to 1. Share n of the world population and firms are assumed to reside in the home country and share $1-n$ in the foreign country. Agents consume consumption goods, supply labor and invest in their capital stock which they rent out to firms. Each firm produces a single differentiated good, whereas labor and capital are assumed to be homogenous and can be substituted across firms without any cost.

2.1 Preferences

Preferences of the representative agent residing in the home country have the following explicit form:

$$U = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{C_s^{1-\sigma}}{1-\sigma} + \frac{\chi}{1-\epsilon} \left(\frac{M_s}{P_s} \right)^{1-\epsilon} + \eta \ln (1 - H_s) \right]$$

Direct utility is derived from the consumption of a basket of differentiated goods C_t, from real money balances $\frac{M_t}{P_t}$, and from leisure $(1-H_t)$. The home agent faces the following intertemporal budget constraint:

$$P_t C_t + P_t V_t + M_t + B_{t+1}^h + e_t B_{t+1}^f + P_t \tau_t = (1+i_t)\, B_t^h + \left(1+i_t^*\right) e_t B_t^f + \Pi_t + W_t H_t + r_t^K P_t K_t + M_{t-1} \qquad (1)$$

Agents can trade only two internationally traded riskless bonds B_t^h and B_t^f, where the former is denominated in the home and the latter in the foreign currency. This implies perfect capital mobility in the sense of Mundell.[6] Nominal expenditures on consumption $P_t C_t$, investment $P_t V_t$, money balances

[5] As the model is very similar to the model derived in Schmidt (2006), the derivation is kept brief and focuses mainly on the innovations.

[6] Mundell (1963, p. 475) states that "the assumption of perfect capital mobility can be taken to mean that all securities in the system are perfect." Note, however, that the *physical* capital stock per se is internationally immobile, as is labor.

M_t, bonds and the payment of nominal lump-sum taxes amounting to $P_t\tau_t$ may not exceed the sum of nominal returns from last period's bonds in terms of the home currency, nominal profits Π_t from the shares of home firms, nominal wage income W_tH_t, nominal rental payments received on the capital stock $r_t^K P_t K_t$, plus last period's money balances M_{t-1}.[7]

The explicit form of the law of motion for capital is:

$$K_{t+1} = (1-\delta)\,K_t + V_t - \frac{\phi}{2}\frac{\{K_{t+1}-K_t\}^2}{K_t} \tag{2}$$

Even though home agents cannot explicitly invest in the foreign capital stock, capital can be transferred from one country to the other, since investment is implicitly assumed to be reversible, i.e. investment can become negative. This implies that home agents can reduce the home capital stock to increase the amount of goods available in the home economy, which can then be exported to the foreign country and integrated in the buildup of the foreign capital stock.[8] Due to the implied trade balance surplus, home agents acquire net foreign assets, i.e. claims on the foreign production, which yield a higher return than home capital. Maximizing expected lifetime utility U results in the following first order conditions of the domestic representative agent:

$$C_t^{-\sigma} = \beta E_t\left[(1+i_{t+1})\left(\frac{P_t}{P_{t+1}}\right)C_{t+1}^{-\sigma}\right] \tag{3}$$

$$\frac{M_t}{P_t} = \left[\chi C_t^{\sigma} E_t\left[\frac{1+i_{t+1}}{i_{t+1}}\right]\right]^{\frac{1}{\epsilon}} \tag{4}$$

$$\eta\frac{1}{(1-H_t)} = C_t^{-\sigma}\frac{W_t}{P_t} \tag{5}$$

$$\left(1+\phi\frac{K_{t+1}-K_t}{K_t}\right)C_t^{-\sigma} = \beta E_t\left[\left(1+r_{t+1}^K-\delta+\frac{\phi}{2}\frac{K_{t+2}^2-K_{t+1}^2}{K_{t+1}^2}\right)C_{t+1}^{-\sigma}\right] \tag{6}$$

$$(1+i_{t+1})\,E_t\left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}}\right] = \left(1+i_{t+1}^{*}\right)E_t\left[\frac{C_{t+1}^{-\sigma}}{P_{t+1}}\left(\frac{e_{t+1}}{e_t}\right)\right] \tag{7}$$

Equation 3 is the Euler equation which determines the optimal intertemporal consumption path. Equation 4 characterizes the money market equilibrium, while Eq. 5 determines optimal labor supply. The agent's aggregate investment decision is determined by Eq. 6. For the assumption of certainty equivalence

[7] For the distribution of profits, I assume that all agents within one country hold equal shares of all firms residing in this country, and home (foreign) firms profits are distributed equally among all home (foreign) agents.

[8] Yet, each change in the size of the home and foreign capital stock is associated with capital adjustment costs, determined by ϕ.

used for the linear approximation below, Eq. 7 reduces to the uncovered interest parity.

2.2 Demand

2.2.1 Consumption

The household's consumption basket is defined as an aggregate of the consumption of home and foreign goods, which takes the explicit form of a CES-function:

$$C_t = \left(n^{\frac{1}{\mu}} \left(C_t^h\right)^{\frac{\mu-1}{\mu}} + (1-n)^{\frac{1}{\mu}} \left(C_t^f\right)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \tag{8}$$

C_t^h and C_t^f are the representative home agent's consumption baskets that consist of domestically produced goods and imported foreign goods respectively.[9] In the following we assume that the consumption baskets of agents in both countries are identical and that the share of home goods consumed depends on the relative size of the home country n. This assumption implies purchasing power parity (PPP) as long as the law of one price holds for all goods. The parameter μ denotes the elasticity of substitution between home and foreign goods. Both C_t^h and C_t^f consist of a weighted average of home and foreign differentiated goods each of which is produced by an individual monopolistic firm. The composition of the commodity basket of home goods consumed by home agents is defined as:

$$C_t^h = \left(n^{-\frac{1}{\theta}} \int_0^n c_t^h \left(z^h\right)^{\frac{\theta-1}{\theta}} dz^h \right)^{\frac{\theta}{\theta-1}}$$

Consumption of foreign goods is allocated analogously:

$$C_t^f = \left((1-n)^{-\frac{1}{\theta}} \int_n^1 c_t^f \left(z^f\right)^{\frac{\theta-1}{\theta}} dz^f \right)^{\frac{\theta}{\theta-1}}$$

The parameter θ denotes the elasticity of substitution between different goods produced within one country, but also governs the magnitude of the markup.

2.2.2 Investment

The composition of investment goods is not obvious, as it might matter for the resulting saving-investment correlations. If investment consisted of

[9] A notational remark: The superscript h (f) denotes goods and prices of home (foreign) producers. Variables marked with an asterisk identify goods that are sold in the foreign market and prices that are charged in the foreign currency.

domestically produced goods only, an increase in home investment would need to be accompanied either by an increase in home production or a reduction in the consumption of home goods. As output is demand determined in the short run, a monetary induced rise in investment is likely to increase home production, leading to a more or less proportionate rise in home savings. Yet, if investment also includes foreign goods, higher investment demand can also be satisfied by a surge in imports, financed by issuing foreign debt, instead of increasing domestic savings. Therefore, investment is assumed to consist of both home and foreign goods in each country.[10] For simplicity, investment features the same composition of home and foreign goods as consumption. Hence, aggregate investment demand of the representative home agent is defined as follows:

$$V_t = \left(n^{\frac{1}{\mu}} \left(V_t^h \right)^{\frac{\mu-1}{\mu}} + (1-n)^{\frac{1}{\mu}} \left(V_t^f \right)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \tag{9}$$

Investment demand for home and foreign goods V^h and V^f are then defined in correspondence to consumption C^h and C^f above.

2.2.3 Aggregate demand

Since all agents residing in one country have identical preferences and face the same restrictions in form of their budget constraints, they will all reach the same demand decisions for consumption and investment. Expenditure minimization for home and foreign consumption and investment then results in the following total demand for the representative foreign good f:

$$\begin{aligned} y_t^f(f) = {} & n \left(\frac{p_t^f(f)}{P_t^f} \right)^{-\theta} \left(\frac{P_t^f}{P_t} \right)^{-\mu} \left[C_t + V_t \right] \\ & + (1-n) \left(\frac{p_t^{f*}(f)}{P_t^{f*}} \right)^{-\theta} \left(\frac{P_t^{f*}}{P_t^*} \right)^{-\mu} \left[C_t^* + V_t^* \right] \end{aligned} \tag{10}$$

and the total demand for the representative home good h:

$$\begin{aligned} y_t^h(h) = {} & n \left(\frac{p_t^h(h)}{P_t^h} \right)^{-\theta} \left(\frac{P_t^h}{P_t} \right)^{-\mu} \left[C_t + V_t \right] \\ & + (1-n) \left(\frac{p_t^{h*}(h)}{P_t^{h*}} \right)^{-\theta} \left(\frac{P_t^{h*}}{P_t^*} \right)^{-\mu} \left[C_t^* + V_t^* \right] \end{aligned} \tag{11}$$

Demand for the representative home good $y_t^h(h)$ consists of demand by home and foreign agents, weighted with the relative country size n, which both depend on the overall level of expenditure on consumption and investment, as

[10] Also note that investment goods account for an important share in the international trade of goods.

well as on the relative price of the representative home good denoted in the relevant currency. Accordingly, $p_t^h(h)$ ($p_t^{h*}(f)$) is the home (foreign) currency price of good h, P_t^h (P_t^{h*}) denotes the price level for the basket of home goods denoted in the home (foreign) currency and P_t (P_t^*) denotes the overall consumer price index in the home (foreign) country in the respective currency. P_t^h is defined as:[11]

$$P_t^h = \left[\frac{1}{n}\int_0^n \left(p_t^h\left(z^h\right)\right)^{1-\theta} dz^h\right]^{\frac{1}{1-\theta}} \tag{12}$$

Correspondingly, the home price index for imported goods from the foreign country P_t^f, is defined as:

$$P_t^f = \left[\frac{1}{1-n}\int_n^1 \left(p_t^f\left(z^f\right)\right)^{1-\theta} dz^f\right]^{\frac{1}{1-\theta}} \tag{13}$$

with $p^f(z)$ as the *home* currency price of the foreign good z. The home consumer price index is then a weighted average of individual home and import goods prices, defined as:

$$P = \left[n\left(P^h\right)^{1-\mu} + (1-n)\left(P^f\right)^{1-\mu}\right]^{\frac{1}{1-\mu}}. \tag{14}$$

2.3 Firms

In an environment of monopolistic competition, each firm will set its price so as to maximize expected profits, taking its individual demand schedule, Eq. 11, into account. Price rigidities à la Calvo (1983) are included.[12] In order to analyze whether the effects on savings and investment correlations in response to a monetary shock are sensitive to different price-setting strategies, two alternative price-setting regimes are considered: producer-currency-pricing (PCP) and local-currency-pricing (LCP).[13] Whereas a PCP firms sets the price for its good in the domestic currency of the producer, independent of the market where the good is sold, the LCP firm is assumed to set two different prices, one for the home market and one for the foreign market, each in the local currency of the market. In the presence of short-run price rigidities, import prices of PCP goods exhibit a complete exchange-rate pass-through while import prices of LCP goods are not affected by a change in the exchange rate.

[11]For an explicit derivation of the price indices, evolving from the expenditure minimization process, the reader is referred to Schmidt (2004), pp. 204–209.

[12]Each firm faces the same constant probability $(1-\gamma)$ every period to change its price next period.

[13]Betts and Devereux (1996, 2000, 2001), Engel (2000) and Schmidt (2006) have shown that the international transmission effects of monetary policy shocks are crucially affected by the way firms set their prices.

2.3.1 Profit maximization

In the presence of price rigidities à la Calvo, firms set prices so as to maximize their expected discounted future profits. The optimal price of the representative home PCP firm at time t, $\widetilde{P}_t^{h,PCP}(h)$, can then be derived as a markup $\left(\frac{\theta}{\theta-1}\right)$ over a weighted average of expected future nominal marginal costs MC_t:[14]

$$\widetilde{P}_t^{h,PCP}(h) = \frac{\theta}{\theta-1} \frac{E_t\left[\sum_{i=0}^{\infty}(\gamma\beta)^i\left(\frac{C_{t+i}}{C_t}\right)^{-\sigma} D_{t,t+i}^{h,PCP} MC_{t+i}\right]}{E_t\left[\sum_{i=0}^{\infty}(\gamma\beta)^i\left(\frac{C_{t+i}}{C_t}\right)^{-\sigma} D_{t,t+i}^{h,PCP}\right]} \tag{15}$$

$D_{t,t+i}^{h,PCP}$ denotes total expected future real sales revenues of the PCP firm, given that the optimal price chosen at time t is still effective. $\beta^i\left(\frac{C_{t+i}}{C_t}\right)^{-\sigma}$ denotes the discount rate at time t of expected time $t+1$ earnings and γ^i is the probability, that the price set at time t is still effective at time $t+1$. Since all PCP firms in the home country face the same constraints, each firm that can adjust its price in period t will choose the same price $\widetilde{P}_t^{h,PCP}(h)$.

The representative LCP firm faces essentially the same optimization problem as the PCP firm, but maximizes profits arising from the home and the foreign market, choosing two different prices, one in the home and one in the foreign currency. Whereas the optimal price for the domestic market is similar to the one of the PCP firm,[15] the optimal export price $\widetilde{P}_t^{h,LCP,*}(h)$ of the representative home LCP firm is derived as:

$$\widetilde{P}_t^{h,LCP,*}(h) = \frac{\theta}{\theta-1} \frac{E_t\left[\sum_{i=0}^{\infty}(\gamma\beta)^i\left(\frac{C_{t+i}}{C_t}\right)^{-\sigma} D_{t,t+i}^{h*,LCP} \frac{MC_{t+i}}{e_{t+i}}\right]}{E_t\left[\sum_{i=0}^{\infty}(\gamma\beta)^i\left(\frac{C_{t+i}}{C_t}\right)^{-\sigma} D_{t,t+i}^{h*,LCP}\right]} \tag{16}$$

Correspondingly, $D_{t,t+i}^{h*,LCP}$ is defined as expected future real sales revenues of the LCP firm—albeit only in the export market. As the LCP price for the foreign market is set in the *foreign* currency, the optimal newly set price also depends on the expected future path of the nominal exchange rate e_{t+i}.

Although individual prices of each firm residing in one country differ, the Calvo pricing allows to define an average price for each type of firm in each country. The home country price index for home PCP goods $P^{h,PCP}$ is then a weighted average of last period's price index and the optimal price at time t:

$$P_t^{h,PCP} = \left[\gamma\left(P_{t-1}^{h,PCP}\right)^{1-\theta} + (1-\gamma)\left(\widetilde{P}_t^{h,PCP}(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{17}$$

[14]For a more detailed derivation of the optimal price for different price-setting strategies, the reader is referred to Schmidt (2006) and Schmidt (2004), p. 212–225.

[15]Note that this holds only for the log-linearized version of the model.

The price index for domestic goods produced by LCP firms evolves analogously:

$$P_t^{h,LCP,*} = \left[\gamma \left(P_{t-1}^{h,LCP,*}\right)^{1-\theta} + (1-\gamma) \left(\widetilde{P}_t^{h,LCP,*}(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{18}$$

Since the optimal price in the domestic market of the LCP firm is identical to the PCP firm's price, the home price index for domestically produced goods, defined in Eq. 12 above, can simply be written as:

$$P_t^h = P_t^{h,PCP} \tag{19}$$

The price index of imported foreign goods P_t^f, on the other hand, is defined as a weighted average of the average prices of foreign LCP and PCP goods, $P_t^{f,LCP}$ and $P_t^{f,PCP,*}$, where the respective weights are determined by the share s of LCP firms:

$$P_t^f = \left[s \left(P_t^{f,LCP}\right)^{1-\theta} + (1-s) \left(e_t P_t^{f,PCP,*}\right)^{1-\theta}\right]^{\frac{1}{1-\theta}} \tag{20}$$

2.3.2 Production

Firms at home and abroad produce under constant-returns-to-scale, employing the following Cobb-Douglas production function: $y_t(h) = A_t K_t(h)^{\alpha} H_t(h)^{1-\alpha}$. A_t represents the common level of technology in the home country, while $K_t(h)$ and $H_t(h)$ denote the individual capital and labor inputs of the representative home firm h. Cost minimization implies that firms will demand factor inputs to satisfy:

$$W_t = MC_t(1-\alpha)\frac{y_t^h(h)}{H_t(h)} = MC_t(1-\alpha)\frac{y_t^h}{H_t} \tag{21}$$

$$P_t r_t^K = MC_t \alpha \frac{y_t^h(h)}{K_t(h)} = MC_t \alpha \frac{y_t^h}{K_t} \tag{22}$$

MC_t denotes the nominal marginal costs of production. Since all firms in one country have to pay the same wage and face the same rental rate for capital, marginal costs are the same across all firms residing in one country.[16]

2.4 Gross national income and savings

As Ricardian equivalence holds in this type of models, assuming a balanced budget has no consequence on the results of the following analysis. For simplicity it is assumed that all seigniorage revenue accruing to the central

[16] For the derivation, the reader is referred to Schmidt (2004), pp. 210–212.

bank is redistributed to agents in form of a lump-sum transfer: $M_t - M_{t-1} = -P_t\tau_t$. This assumption reduces the home economy's budget constraint to:

$$P_tC_t + P_tV_t + B^h_{t+1} + B^f_{t+1}e_t = (1+i_t)\,B^h_t + \left(1+i^*_t\right)B^f_te_t \\ + \Pi_t + W_tH_t + P_tr^K_tK_t \tag{23}$$

Gross national savings are defined as gross national income—resulting from factor income, profits and returns on interest—less expenditures on consumption.[17] Nominal savings P_tS_t can then be written as:

$$P_tS_t = \underbrace{\left[i_tB^h_t + i^*_tB^f_te_t + \Pi_t + W_tH_t + P_tr^K_tK_t\right]}_{\equiv P_t\cdot Y_t^{GNI,h}} - P_tC_t \tag{24}$$

Since all agents residing in one country are assumed to hold identical shares of all domestic firms, gross national income can easily be expressed in terms of production. Gross national *real* income, defined as $Y_t^{GNI,h}$, then consists of the value of domestic production and net interest payments from abroad, both deflated by the consumer price index:

$$Y_t^{GNI,h} = \frac{P^h_t}{P_t}\left[y_t^{h,PCP} + (1-s)\,y_t^{h,PCP,*}\right] + s\frac{e_tP_t^{h,LCP,*}}{P_t}y_t^{h,LCP,*} + \frac{i_tB^h_t + i^*_tB^f_te_t}{P_t} \tag{25}$$

Real income of home agents increases with higher sales—both in the home and the foreign market—with improving terms of trade and with higher real returns on net foreign assets. As is obvious from Eq. 24, the evolution of real income is crucial for real domestic savings S_t. With current consumption being mainly determined by the real interest rate, real savings evolve as the residual of real income and consumption. Hence, savings increase when domestic production, which is demand determined in the short run, rises by more than domestic consumption. Substituting Eq. 24 in Eq. 23, we obtain:

$$P_tV_t = P_tS_t - \underbrace{\left(B^h_{t+1} - B^h_t\right) + \left(B^f_{t+1} - B^f_t\right)e_t}_{=B_{t+1}-B_t} \tag{26}$$

From Eq. 26 it becomes evident that investment in the home capital stock will either be financed by home savings, or through imports from abroad by accumulating foreign debt, depending on relative costs. In the steady state, the current account needs to be balanced, i.e. $B_{t+1} - B_t = 0$. Thus, the definition in Eq. 26 implies that home agent's steady-state expenditures on investment need to coincide with the home economy's savings as defined above. Yet, in response to an exogenous shock, home savings and investment might be affected differently as will be shown below.

[17] In the empirical studies reviewed in the introduction, gross national savings are defined as gross national income less private and government consumption and thus include both private and government savings. Note that as the latter is 0 in the model, the definition of savings is identical.

2.5 Market clearing and equilibrium

In equilibrium, all goods, factor and asset markets need to clear in the home and the foreign economy. In the home goods market, aggregated demand consists of demand for LCP and PCP goods:

$$Y_t^h = s y_t^{h,LCP} + (1-s)\, y_t^{h,PCP} \tag{27}$$

Since all home firms produce with the same capital-labor ratio, total supply in the home country can be written as:[18]

$$Y_t^h = \frac{1}{n}\int_0^n A_t K_t^{\alpha}\left(z^h\right) H_t^{1-\alpha}\left(z^h\right) dz^h = A_t K_t^{\alpha} H_t^{1-\alpha} \tag{28}$$

The foreign goods market clears analogously. The home (foreign) money market is in equilibrium if national money demand corresponds to the exogenous supply of home (foreign) currency provided by the national central bank. The explicit form of the money supply processes will be defined below. Bond markets clear in equilibrium if aggregate *world* assets B_t are equal to zero in all periods.

Equilibrium is characterized by Eqs. 2–6, 14–22, 24, 27, 28, and their foreign counterparts, demand Eq. 11 for both LCP and PCP firms in the home and the foreign economy, as well as Eqs. 7, 23 and the bonds market equilibrium, which gives 41 equations. This is a dynamic system in the following 41 variables, given by X_t

$$\begin{aligned} X_t = \{ & C_t, C_t^*, H_t, H_t^*, V_t, V_t^*, K_t, K_t^*, W_t, W_t^*, r_t^k, r_t^{k*}, i_t, i_t^*, MC_t, MC_t^*, e_t, B_t^h, \\ & B_t^f P_t, P_t^*, P_t^h, P_t^f, P_t^{h*}, P_t^{f*}, \widetilde{P}_t^{h,PCP}, \widetilde{P}_t^{h,LCP,*}, \widetilde{P}_t^{f,PCP,*}, \widetilde{P}_t^{f,LCP}, P_t^{h,PCP}, \\ & P_t^{h,LCP}, P_t^{f,PCP}, P_t^{f,LCP}, Y_t^h, Y_t^f, y_t^{h,PCP}, y_t^{h,LCP}, y_t^{f,PCP}, y_t^{f,LCP}, S_t, S_t^* \} \end{aligned}$$

The model is solved by linearizing around the symmetric steady state, where neither country owns net foreign assets.[19]

2.6 Parametrization

The chosen parametrization is presented in Table 1. The quarterly real interest rate is set to 1% in the steady state. The consumption elasticity of money demand ($\frac{\sigma}{\epsilon}$ in the model) is set to unity, for the interest elasticity of money demand ($-\frac{\beta}{\epsilon}$ in the model), the estimate from Chari et al. (2002) of −0.39 is employed.[20] The benchmark values for money demand elasticities imply that σ is about 2.5. In line with findings which suggest a markup of about 10% in

[18]The division by n is needed to put aggregate production in the same per capita form as aggregate demand and the input factors.

[19]For the solution of the model, the MATLAB code provided by Schmitt-Grohé and Uribe (2004) is employed.

[20]Mankiw and Summers (1986) obtain an estimate of −0.051, which is at the lower and of the values found. The main results are unaffected if this value is employed.

Table 1 Calibrated parameter values

Parameter	Value
σ	2.5
χ	1
θ	10
ϵ	2.5
δ	0.021
μ	1.5
ϕ	8
β	$\frac{1}{1.01}$
s	0/1
η	2.8
α	$\frac{1}{3}$
γ	0.75

the US, I assume $\theta = 10$. The capital share α is assigned a value of $\frac{1}{3}$, while the rate of depreciation δ is set to 0.021, which implies an annual depreciation rate of about 10%, corresponding to the typical estimates for US data. The steady state share of labour, $\overline{H}_0$, is set to 0.3. For simplicity, the relative preference parameter for real balances, χ, is assumed to be 1. The last two assumptions further determine η to be 2.8. γ is set to 0.75 which implies that the average time between price adjustment for a firm is one year. The value for capital adjustment costs ϕ is set to 8, which induces a relative investment response which is in line with the findings of VAR analyses. Finally, the elasticity of substitution between home and foreign goods μ is set equal to 1.5 as found by Hooper and Marquez (1995, Table 4.1) for the US. The degree of pricing to market is either set to 0 or 1.[21] The relative country size n in the benchmark is set to 0.5 which implies that both countries are large and of equal size. Yet, also a relative size of 0.1 as a small country case is analyzed.

For the determination of the properties of the exogenous money supply processes in the home and the foreign country, logged narrow money supply (M1) for both the US and a weighted average of the remaining G7 countries was HP filtered and a first order vector autoregression (VAR) was estimated for the period 1970:Q2–2005:Q4.[22] The estimation output is presented below:

$$\begin{bmatrix} m_{t+1}^{US} \\ m_{t+1}^{G6} \end{bmatrix} = \begin{bmatrix} \underset{(0.03036)}{0.9378} & \underset{(0.02436)}{0.021704} \\ \underset{(0.05763)}{-0.082545} & \underset{(0.00127)}{0.835035} \end{bmatrix} \cdot \begin{bmatrix} m_t^{US} \\ m_t^{G6} \end{bmatrix} + \begin{bmatrix} \epsilon_t^{US} \\ \epsilon_t^{G6} \end{bmatrix}$$

with m_t^{US} and m_t^{G6} as the HP filtered logged narrow money supply in the US and the remaining G7 countries, respectively, and Var $\epsilon_t^{US} = 0.0000883$, Var $\epsilon_t^{G6} = 0.0000568$, Cov $\left(\epsilon_t^{US}, \epsilon_t^{G6}\right) = 0.00000254$. Standard errors are reported in parenthesis. While the estimates of the diagonal elements are highly significant, this is not true for the off-diagonal elements. This result is in line

[21] The case of intermediate LCP with $s = 0.5$ is considered in the second simulation excercise.

[22] US and G7 data obtained from the OECD (Main Economic Indicators).

with Kollmann (2001) . For the simulations, I assume the following process for money supply:

$$\begin{bmatrix} m_{t+1} \\ m^*_{t+1} \end{bmatrix} = \begin{bmatrix} 0.89 & 0 \\ 0 & 0.89 \end{bmatrix} \cdot \begin{bmatrix} m_t \\ m^*_t \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \epsilon^*_t \end{bmatrix}$$

with ϵ_t and ϵ^*_t joint normally distributed with mean zero, variance 0.00007225 and covariance 0.00000254.

3 Results

In this section, I will first present and discuss the impulse responses (IR) obtained for a 1% permanent increase in home money supply for alternative assumptions on price-setting behavior of firms and different country sizes. Subsequently, the results obtained from multiperiod simulations of the model for shocks to money supply will be presented and compared to 'stylized facts' of historical business cycle data for the US.

3.1 Large country

Figure 1 displays the IR for complete PCP in both countries, when both countries are large and of equal size. The plotted impulse responses are percentage deviations from respective steady-state values, except for the interest rates and the current account. For the interest rates, the deviations depicted are in percentage-points, while the current account and the net foreign asset position is defined in percent of steady-state home nominal income. Solid (dashed) lines show the responses of the first (second) variable. The horizontal axes depict the number of quarters.

In response to the surprise increase in home money supply in period 1, home savings as well as home investment increase. At the same time, savings and investment in the foreign country rise as well. Since the initial increase relative to the steady-state value in home savings of 2.8% dominates the initial rise in home investment of 2.0%, the home country runs a current account surplus, which amounts on impact to 0.1% of nominal steady-state income.[23] As can be seen from the solid line, the current account surplus then declines in line with the excess of home savings over investment.

The propagation mechanism is as follows. To restore money market equilibrium in the home country, the home nominal (and real) interest rates decline. As PPP holds with complete PCP, the real exchange rate is unaffected by the shock, which leaves no room for a real interest rate differential between the home and the foreign country. Hence, the decline in real interest rates is identical in both countries, stimulating consumption and investment demand

[23] Steady-state savings and investment both correspond to about 20% of nominal steady-state GDP, while consumption accounts for the remaining 80%.

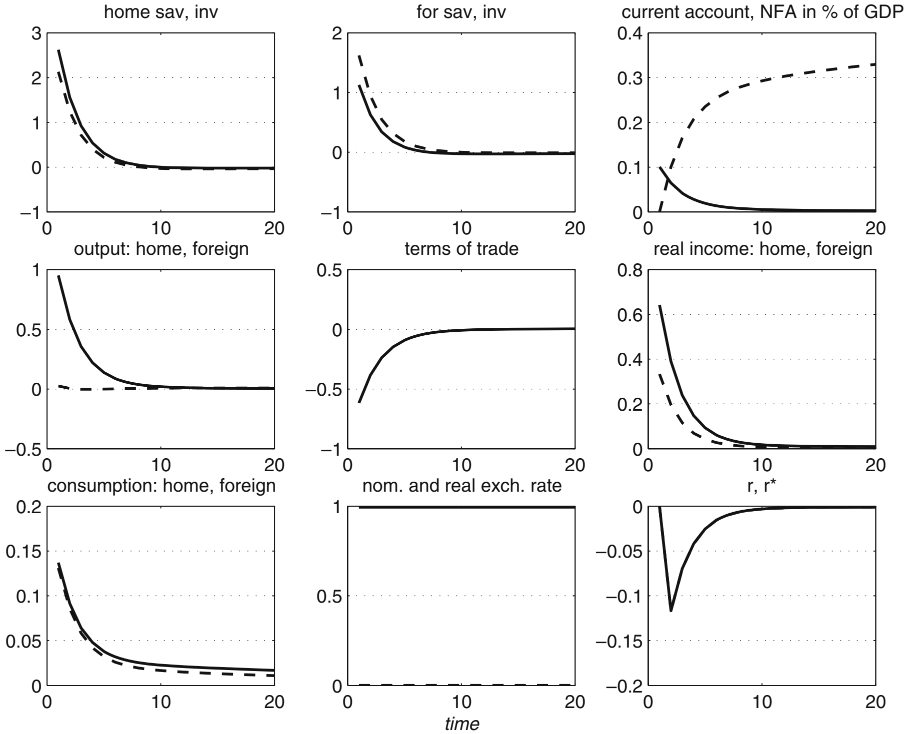

Fig. 1 IR to a permanent rise in M for $n = 0.5$ and complete PCP

in the two economies alike.[24] As import prices exhibit complete exchange-rate pass-through, the increase in world demand is directed towards goods produced in the home country. At the same time, both home and foreign real income increase, although only home output is affected by the shock. The rise of foreign real income is a result of the deterioration of the home economy's terms of trade. The terms of trade deteriorate as, with prices pre-set in the producer's currency, home country's import prices rise in terms of the home currency. The increase in real income allows foreign agents to raise their savings even for the higher level of consumption. Yet, savings in the home economy rise by more than investment, and home agents build up their stock of net foreign assets.

The corresponding IR for complete LCP are shown in Fig. 2. As before, an unanticipated increase in home money supply raises home savings as well as home investment in the short run. Hence, the high similarity of national savings and investment responses are independent of the price-setting behavior. This finding supports the VAR results by Kim (2001) of high comovements in US

[24] Consumption responds to a drop in the real interest rate via the Euler equation. This in turn reduces the opportunity costs of investment, which increases as well.

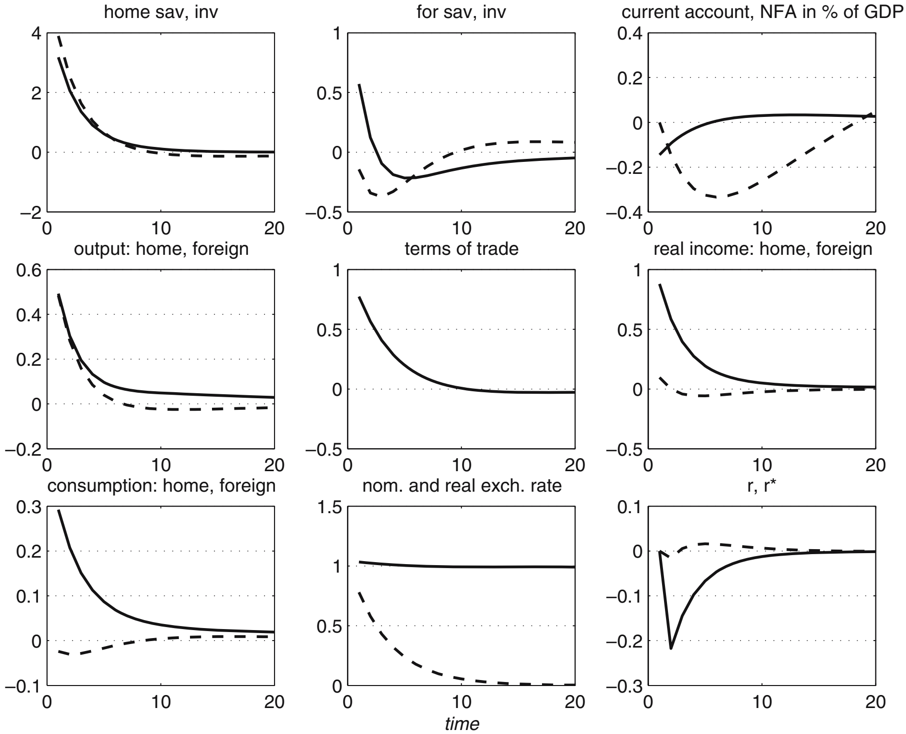

Fig. 2 IR to a permanent rise in M for $n = 0.5$ and complete LCP

savings and investment in response to a domestic monetary policy shock. On the contrary, foreign economy's savings rise, whereas investment falls in the short run. When all producers set their export prices in the local currency of the export market, there is no exchange-rate pass-through to import prices. As home import prices do not rise in proportion to the devaluation, the increase in real money supply in the home economy is higher, which causes a larger drop in the home interest rate. In response, the increase in home consumption and investment is larger (0.3 and 4% respectively). On the other hand, there is no decline in foreign import prices and thus in the foreign consumer price level, which prevents a reduction in foreign nominal and real interest rates, as depicted in Fig. 2.[25] Instead, with a number of firms already adjusting prices in the short run, the foreign consumer price level is even higher than before, which raises the foreign real interest rate. Therefore, foreign consumption and investment fall. The initial increase in foreign savings of 0.6% is stimulated by the decline in foreign consumption joint with a temporary rise in foreign real income. Yet, because of the deterioration of the foreign

[25] With local currency pricing, PPP no longer holds and home and foreign real interest rates can diverge.

Table 2 S–I-Correlations for monetary shocks in the home economy only

Correlations	Equal size		
	PCP	LCP	$s = 0.5$
S/I	0.999 (0.000)	0.995 (0.003)	0.997 (0.001)
S^*/I^*	0.997 (0.001)	0.039 (0.028)	0.956 (0.024)

country's terms of trade the rise in foreign GNI is negligible, even though foreign output increases by 0.5%. Foreign output rises for complete LCP since the expenditure-switching effect is repressed and the increase in home agents' demand is directed to *both* home and foreign goods. The resulting impulse response functions for foreign savings and investment suggest a low degree of correlation, which is documented in Table 2 below.

3.2 Small country

Figure 3 displays the IR for complete PCP in both countries, when the home country is relatively small and represents only 10% of the world population. Again, savings and investment increase in the home economy, although the

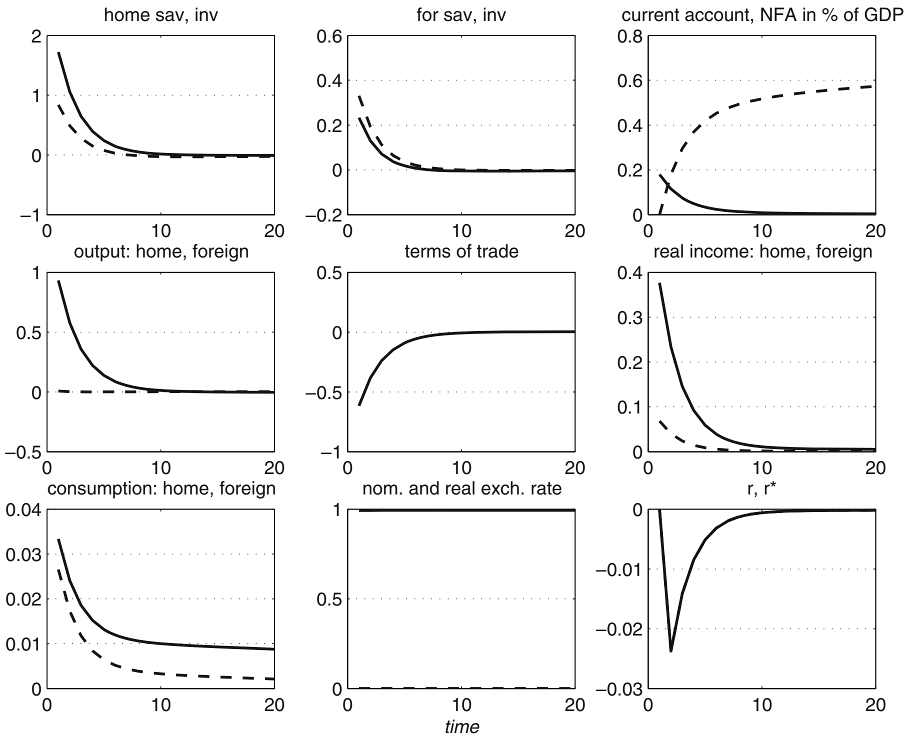

Fig. 3 IR to a permanent rise in M for $n = 0.1$ and complete PCP

increase in investment is less than before. The reason is that in the small country case, the 1% increase in home nominal money supply reduces the real world interest rate by less than before, as the monetary impulse is smaller. Thus, the effects on consumption and investment in both countries are reduced. At the same time, the difference between home savings and investment rises, because the relative increase in demand for home products still amounts to almost 1%. This effect is also reflected in the size of the current account surplus, which is now twice the size. Compared to the benchmark scenario where both countries are of equal size, the larger foreign country is now hardly affected by the home monetary expansion, although savings and investment still comove. Note that real income in the foreign economy hardly increases, as the terms of trade effect for a large country with a low import share is negligible.[26]

3.3 Simulation results and correlations

This section aims at an empirical validation of the presented model by comparing simulation results to 'stylized facts' of business cycle data for the US.[27] For this purpose, the model economy was hit by a sequence of shocks to money supply with the properties derived in Section 2.6. Yet, in a first exercise, only shocks to *home* money supply are considered. The resulting S–I-correlation coefficients including the standard errors are presented in Table 2.[28] Note that also an intermediate case of LCP with $s = 0.5$ is included. The results correspond to the findings of the impulse response analysis of a one time permanent shock. As before, the correlation of home savings and investment induced by home monetary shocks is high and independent of the price-setting behavior. On the contrary, the correlation of foreign savings and investment is 0 for complete LCP. Yet, for intermediate cases of LCP, the correlation of foreign savings and investment is found to remain high.

The corresponding correlations in response to monetary shocks in *both* countries are reported in Table 3. The correlation coefficients of national savings and investment for the alternative scenarios considered are given in the first row. As can be seen, the correlation coefficient between domestic savings and investment is high in all cases, and independent of the price-setting behavior of firms. Thus, the positive correlation induced by domestic monetary policy shocks dominates. Yet, the country size influences the resulting correlation of domestic savings and investment, which is substantially lower for the small country case, but remains higher than the estimated correlation coefficient of 0.796 for the US.[29]

[26]The import share is determined by the relative country size, i.e. if the foreign country represents 90% of the world economy, its import share is 10% in the steady state.

[27]Quartely data from 1970 to 2005 from the OECD (Main Economic Indicators) and the IMF (International Financial Statistics) were used to compute the correlations.

[28]Each simulation was conducted for 100 periods (quarters). To compute the standard errors, 10,000 simulations were conducted per case.

[29]As the simulated correlations are conditional on monetary shocks only, the comparison to unconditional correlations in the data is not fully valid, but nevertheless provides a first impression.

Table 3 Correlations for monetary shocks in both countries

Correlations	Equal size			Small country			US/G6
	PCP	LCP	$s = 0.5$	PCP	LCP	$s = 0.5$	
S/I	0.955 (0.013)	0.967 (0.009)	0.995 (0.002)	0.869 (0.035)	0.896 (0.026)	0.980 (0.009)	0.796
Y/Y^*	0.044 (0.141)	0.944 (0.031)	0.595 (0.094)	0.045 (0.141)	0.965 (0.020)	0.660 (0.081)	0.655
C/C^*	0.993 (0.005)	−0.178 (0.158)	0.462 (0.131)	0.996 (0.003)	−0.147 (0.160)	0.514 (0.120)	0.509
I/I^*	0.979 (0.006)	−0.183 (0.145)	0.418 (0.123)	0.989 (0.003)	−0.154 (0.144)	0.463 (0.114)	0.545

In order to put the results into a different perspective, Table 3 also presents the cross-country correlations for consumption, investment and output. As PPP holds for the assumption of PCP, there is complete risk sharing and consumption is perfectly correlated internationally, while production at home and abroad are uncorrelated according to these results. However, in the data, the (unconditional) cross-country correlation of output is higher than the one for consumption. This implication of the model is also present in international RBC-models, where this feature is commonly referred to as the 'quantity anomaly'. For the assumption of complete LCP, on the other hand, the positive correlation of home and foreign consumption is lost. Instead, consumption in one country seems to increase at the expense of the other country's consumption. Yet, production is highly correlated for complete LCP, as the expenditure-switching effect is extenuated. Interestingly, for the assumption of an intermediate degree of LCP ($s = 0.5$) the correlations induced by monetary policy shocks are very much in line with the unconditional correlations in the data. In particular, the cross-country correlation of output is higher than for consumption and investment, and all correlations are positive. The reason for this outcome is that with partial LCP, the monetary policy expansion in one country is still in part passed on to the foreign country, increasing foreign demand and leading to a positive cross-country correlation. On the other hand, the expenditure-effect is extenuated for half of the goods, which induces a considerable amount of comovement in output.[30]

4 Conclusion

This paper addresses the issue of saving-investment correlations in response to monetary policy shocks. High correlations between domestic savings and investment both for cross-sectional and time-series data are a robust finding for most OECD countries, even for more recent data. As financial markets are more and more internationally integrated, the high correlations found

[30]Note, however, that this result only holds for monetary shocks. As soon as technology shocks are included, the impact of LCP is negligible.

should not conflict with international capital mobility. Therefore, researchers have been engaged in building models assuming perfect capital mobility which generate high correlations for domestic savings and investment in response to exogenous productivity shocks. However, empirical evidence by Kim (2001) shows that the unconditional correlations found in the data are not fully explained by shocks to productivity. In this paper, the question is raised whether monetary policy shocks can contribute to the saving-investment correlation and thus help to explain the Feldstein–Horioka puzzle. For this purpose, we investigate if a two-country model in the tradition of the New Open Economy Macroeconomics with capital mobility generates high correlations conditional on monetary policy, even for perfect capital mobility. We find that for the country originating monetary policy shocks, savings and investment responses are highly correlated. This finding is in line with the evidence from VARs for the US established by Kim (2001). While the decline in the real interest rate always induces an increase in home investment (and consumption) in response to the monetary expansion, the terms of trade response assures that the rise in home national income exceeds the increase in consumption even for local currency pricing: In the presence of pre-set prices in the foreign currency, export prices *increase* with a home currency devaluation whereas import prices remain constant, and the terms of trade improve. Hence, home savings rise as well, independent of the price-setting behavior of firms. In contrast, the effect on savings and investment in the foreign country highly depends on the price-setting strategy of firms. For producer-currency pricing, foreign savings and investment equally exhibit a high conditional correlation in response to monetary shocks. However, as for the assumption of local currency pricing the foreign real interest rate does not decline, the induced saving-investment correlation is basically zero. It was also shown that in response to monetary shocks in both countries, the high correlations between domestic savings and investment persist, independent of the price-setting behavior of firms. Hence, the results presented in this paper support the idea that shocks to monetary policy can contribute to the unconditional correlation of domestic savings and investment found for many industrialized countries, even when capital is perfectly mobile across countries.

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